Fw: Simulacra and Simulation

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Date: Thursday, July 1st, 2021 at 12:50 PM

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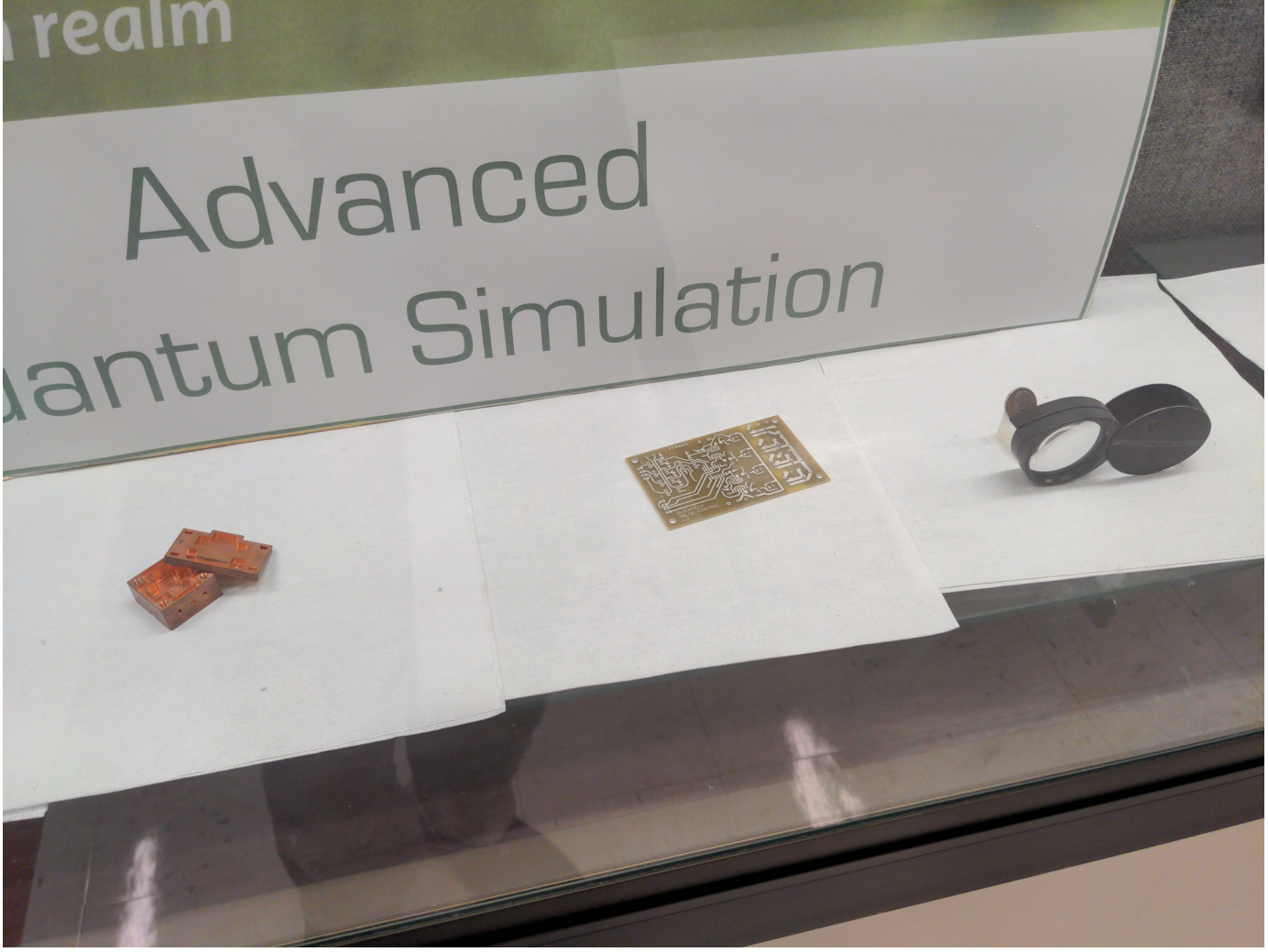
Sent: Monday, May 3, 2021, 10:52:43 PM EDT
Subject: Simulacra and Simulation

Simulacra and Simulation

"M", Tristan-Gan MIANO
May 4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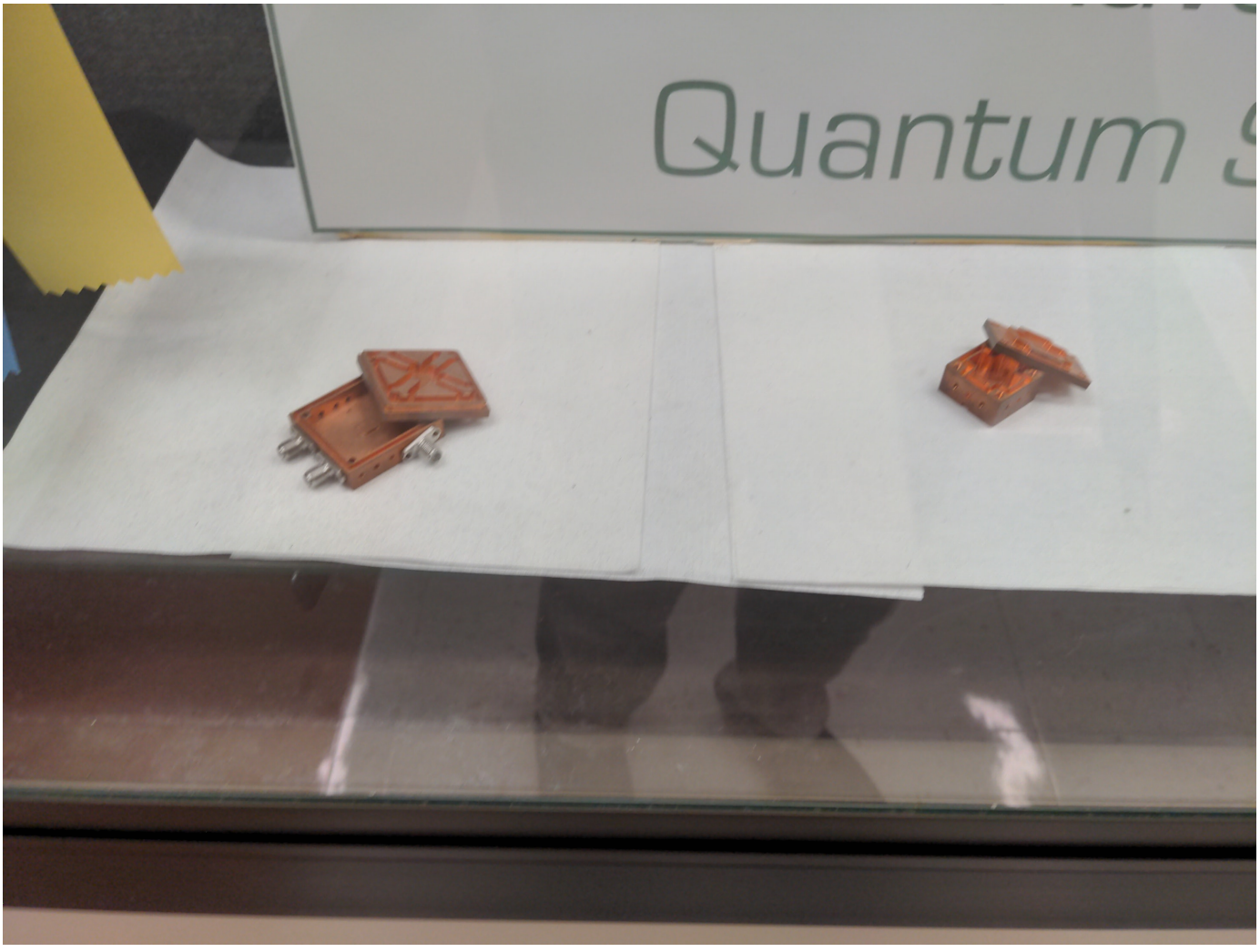
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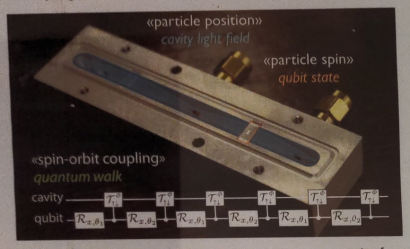
Quantum simulation of topological material

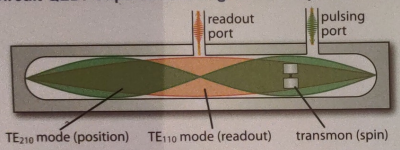
The direct measurement of topological invariants in both engineered and naturally occurring quantum materials is a key step in classifying quantum phases of matter. Here we motivate a toolbox based on time-dependent quantum walks as a method to digitally simulate single-particle topological band structures. Using a superconducting qubit dispersively coupled to a microwave cavity, we implement two classes of split-step quantum walks and directly measure the topological invariant (winding number) associated with each.



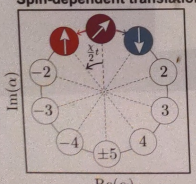
The measurement relies upon interference between two components of a cavity Schrödinger cat state and highlights a novel refocusing technique which allows for the direct implementation of a digital version of Bloch oscillations. Our scheme can readily be extended to higher dimensions, whereby quantum walk-based simulations can probe topological phases ranging from the quantum spin Hall effect to the Hopf insulator.

Quantum Walks with Superconducting circuits

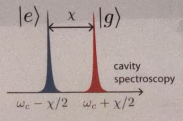
Circuit QED: Superconducting Qubit coupled to Cavity



Spin-dependent translation via dispersive coupling



$$H = \hbar\chi \hat{a}^\dagger \hat{a} \frac{\sigma_z}{2}$$



Emerging Topological Bandstructure in Quantum Walks

Split-step Quantum Walk Protocol

1. Rotate spin by θ_1

$\hat{R}(\theta) = e^{i\theta\hat{\sigma}_x/2}$

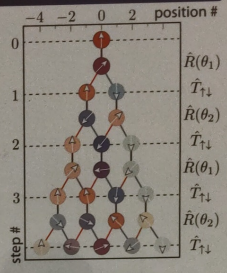
2. Spin-dependent translation

$T_{\uparrow\downarrow} = \sum_x |x\rangle\langle x+1|\otimes|\uparrow\rangle\langle\uparrow| + |x\rangle\langle x-1|\otimes|\downarrow\rangle\langle\downarrow|$

3. Rotate spin by θ_2

4. Spin-dependent translation

5. repeat...



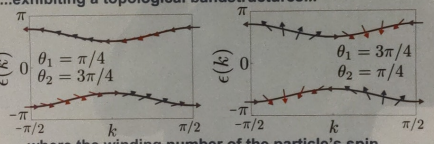
The quantum walk unitary...

$$U_{SS} = \hat{T}_{\uparrow\downarrow}\hat{R}(\theta_2)\hat{T}_{\uparrow\downarrow}\hat{R}(\theta_1) = e^{i\vec{k}\hat{\sigma}_z} e^{i\frac{\theta_2}{2}\hat{\sigma}_z} e^{i\vec{k}\hat{\sigma}_z} e^{i\frac{\theta_1}{2}\hat{\sigma}_z} = e^{i\hat{H}_{\text{eff}}}$$

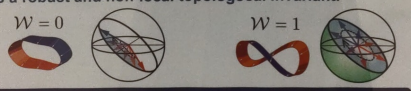
... simulates an effective spin-orbit lattice Hamiltonian...

$$\hat{H}_{\text{eff}} = \epsilon(\hat{k})\ \hat{\sigma}.\vec{n}(\hat{k})$$

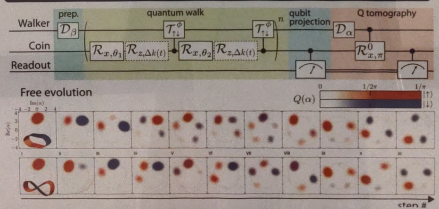
...exhibiting a topological bandstructures...



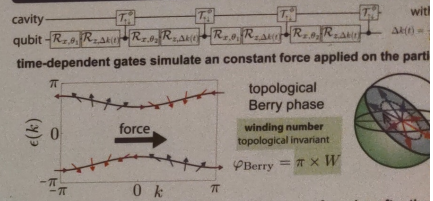
...where the winding number of the particle's spin is a robust and non-local topologocal invariant.



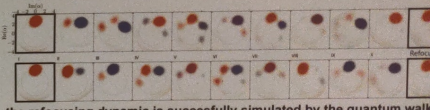
Observing Spin-Orbit Dynamics of the Light Field



Time-dependent Quantum Walk: Digital Bloch Oscillations



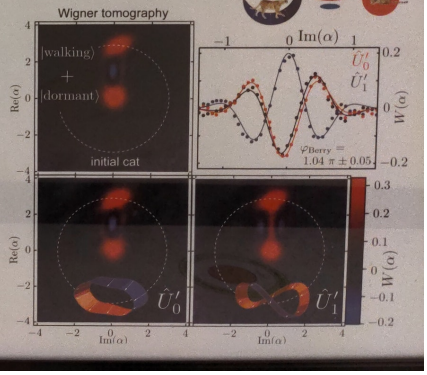
The constant force leads to Bloch oscillation, a refocusing after the traversal of the Brouillon zone.
A topological Berry phase is picked up by the particle's wavefunctio

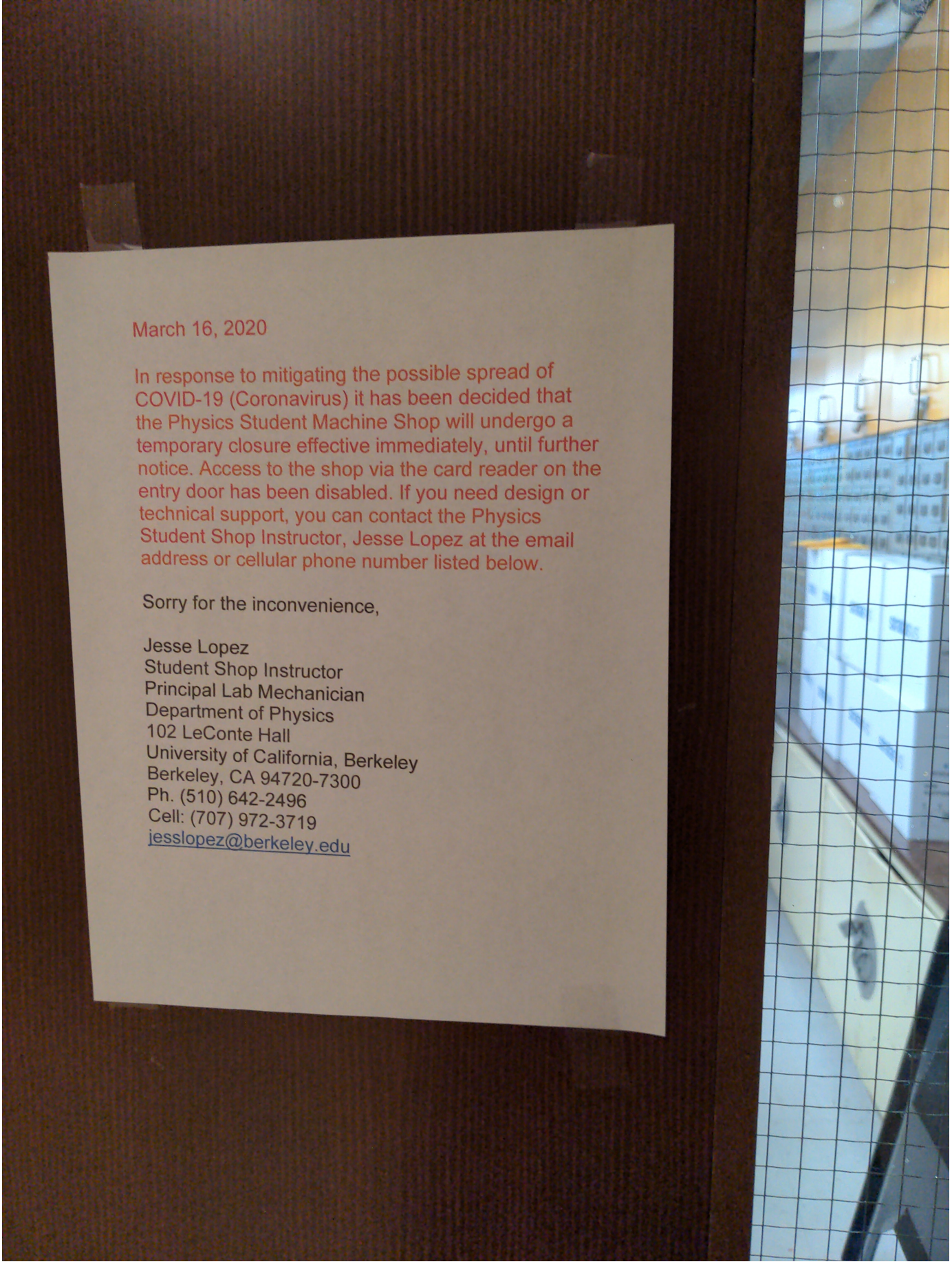


the refocusing dynamic is succesfully simulated by the quantum walk

Directly Observing Topological Invariants with Cats

The topogical Berry phase is revealed with Shrödinger's cat interferometry. The winding number encoded in the Berry phase can be measured in the interference pattern between the walking and dormant part of the cat.





March 16, 2020

In response to mitigating the possible spread of COVID-19 (Coronavirus) it has been decided that the Physics Student Machine Shop will undergo a temporary closure effective immediately, until further notice. Access to the shop via the card reader on the entry door has been disabled. If you need design or technical support, you can contact the Physics Student Shop Instructor, Jesse Lopez at the email address or cellular phone number listed below.

Sorry for the inconvenience,

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